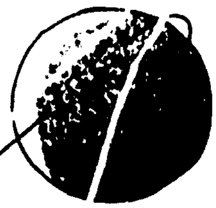


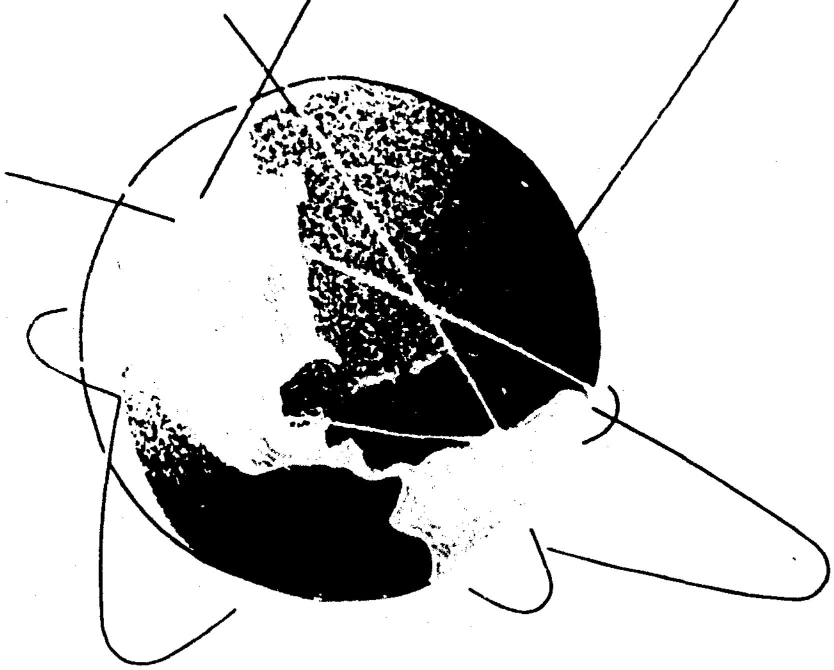
GROUND IMPACT SHOCK MITIGATION CARGO TRAILER M101, 3/4-TON

BY

DAVID G. WIEDERANDERS

EMRL TR 1025

JULY 1967



ENGINEERING MECHANICS RESEARCH LABORATORY
THE UNIVERSITY OF TEXAS · AUSTIN, TEXAS

EMRL TR 1025

GROUND IMPACT SHOCK MITIGATION CARGO TRAILER M101, 3/4-TON

by

David G. Wiederanders

U. S. ARMY NATICK LABORATORIES
AIRDROP ENGINEERING LABORATORY

Project No. 1F121401D195

CONTRACT DA 19-129-AMC-582(N)

TR 65-51-AD

ENGINEERING MECHANICS RESEARCH LABORATORY

THE UNIVERSITY OF TEXAS

Austin, Texas

July 21, 1967

PREFACE

This report is the third in a series dealing with high velocity dropping of military vehicles under Contract DA-19-129-AMC-582(N) with the U. S. Army Natick Laboratories. The first report in the series is entitled Ground Impact Shock Mitigation-M-151 Utility Vehicle (Jeep). The second report is entitled Ground Impact Shock Mitigation Cargo Truck, 3/4-Ton M37.

These vehicles, as well as the M101 trailer discussed in this report were the subjects of previous studies conducted by the Structural Mechanics Research Laboratory under Contract DA-19-129-QM1383. In these earlier studies, the damage susceptibilities of the vehicles were investigated with the impact velocities limited to a maximum of 30 fps. This was the impact velocity specified at that time for airdrop. The design acceleration at that time had been set somewhat arbitrarily at 16g. Cushioning systems which provided adequate protection and a drive-on, drive-off capability for the specified drop conditions were developed and described in the reports issued.

For the present investigation, the only limitation on the impact velocity was the height of the drop facility. For the trailer, this was a drop from a height of about 47 feet. This produced an impact velocity of about 55 fps. No limitation was placed on the design acceleration other than that the vehicle should be adequately cushioned. The maximum design acceleration used was 30g and this provided adequate cushioning for the vehicle.

A drive-on, drive-off capability was not designed into the cushioning system since this was primarily a feasibility study.

Recommendations are given for improvements in the design of the vehicle to improve its performance characteristics in airdrop.

E. A. Ripperger, Director
Engineering Mechanics Research Laboratory
The University of Texas
Austin, Texas

October 3, 1967

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

The present investigation and test series involving the M101 3/4-ton cargo trailer has consisted of five drops of the vehicle at impact velocities ranging from 25.4 fps, for the initial drop, to 55 fps for the fifth and final drop of the series. During the series, the design impact acceleration was varied from 20-30g. The cushioning system used for each drop of the series is described and the damage sustained by the vehicle during that drop is discussed. It is concluded that this vehicle can be dropped at impact velocities up to 50 fps without any damage, if a properly designed cushioning system is employed to dissipate the energy of the drop.

Recommendations for improvements, from the airdrop standpoint, in the design of the vehicle are included.

INTRODUCTION

During the past several years, the nominal design impact velocity for the airdrop of equipment and supplies has been 25 feet per second. This value has been maintained as the upper limit of the impact velocity range which is encountered in an actual airdrop situation. Impact velocities as low as 15 fps are frequently encountered under these conditions and must therefore be taken into consideration when designing the cushion-system for a specific vehicle. This lower value of impact velocity, however, presents no additional problem in the design of an effective cushioning system, as the system will usually perform effectively at impact velocities lower than those for which it was designed. There are, however, other problems encountered when drops are made at low impact velocities. As the impact velocity is reduced, the dispersion of the dropped material is increased. This in turn decreases the accuracy of the drop insofar as hitting the target is concerned. Also, the additional time the equipment is in the air increases the danger from possible enemy action. These problems coupled with the study by Turnbow and Steyer[1*], which showed that the cost of airdrop can be reduced appreciably by using a higher impact velocity, employing relatively inexpensive paper honeycomb to dissipate the energy of the drop, rather than the large expensive parachute required to achieve the 15-25 fps impact velocities, have prompted the investigation of the feasibility of dropping

* Superscript numerals indicate references listed at the end of the report.

vehicles at impact velocities higher than 25 fps.

In theory, at least, it is possible to cushion a vehicle so that it will survive an impact of any velocity, but there are other considerations. For example, the space available in aircraft is limited. This obviously places a limit on the impact velocity that can be sustained because the volume of cushioning material increases as the square of the impact velocity. In addition, the stability of the cushioning system becomes a serious problem as the height of the cushioning stack increases.

In order to study some of the practical problems of cushioning vehicles against high impact velocities; to discover some of the hidden problems; and to determine the maximum practical impact velocity for a specific vehicle; the program of drops of the M101 Cargo Trailer, which is reported here, was undertaken.

The primary objectives of this investigation have been:

1. to verify that the vehicle could be successfully dropped at impact velocities as high as 50 fps,
2. to determine the design acceleration that would be required for such a drop,
3. to work out the essential details of a prototype cushioning system, and
4. to observe the damage susceptibility of the vehicle.

The collection of data regarding the damage susceptibility of certain specific vehicles is but one phase of the research program which is intended to eventually put the design of

cushioning systems for the airdrop of equipment on a firm engineering basis. However, a standard cushioning system applicable to all vehicles is not feasible. Hence, each vehicle must have its own system, and although these differ somewhat in detail, they should all conform to the basic principles of cushioning design as those principles are now understood.

PROCEDURE

In order to ascertain the effectiveness of the initial cushioning design for this vehicle, it was decided to start with a 20g impact acceleration and a drop height of 10 feet, and to gradually increase to higher impact velocities and design accelerations using the results of the tests for guidance in selecting the parameters for subsequent tests.

A cushioning development test series[2] had been conducted for this vehicle several years ago in which several systems were tested for their effectiveness in protecting the vehicle from damage. The results of these tests coupled with the knowledge which has been gained since that time were used to design the initial cushioning system.

The vehicle used for this test series was an M101, 3/4-ton Cargo Trailer supplied by the U. S. Army Tank-Automotive Center under arrangements made through the U. S. Army Natick Laboratories.

In order to prevent undue damage to the trailer, the top and siderails were removed. Also removed were the stop light and blackout markers. The vehicle was further adapted by installing lifting plates on each of the wheels, and a plywood load pallet in the bed of the trailer. This loadspreader was suggested by previous experience with the M37 truck. It was supposed to prevent undue bending in the floor of the trailer due to the 1500 lb. dead load of sandbags used to simulate actual loaded conditions of the vehicle throughout the test series.

As part of the drop program on the M37 truck[3], tests were made on the available honeycomb cushioning material to determine the average crushing stress and energy-absorption characteristics. The results of these tests were used to provide guidance for the development of an effective cushioning system for the M101 and M37.

Drop Program

The program followed in this test series called for the first drop to be from a height of 10 feet with a design acceleration of 20g. In subsequent drops, both the height and design acceleration were increased as seemed warranted by the results of previous test. This was to allow an effective cushioning system to be designed and tested at lower impact velocities before relying on the system at the higher impact velocities and accelerations called for in later phases of this program. By this plan, it was hoped that the limits of the vehicle could be approached without critically damaging the vehicle. Hence, each drop was designed to test changes made in the cushioning system or to proceed to the next phase of the drop program.

In preparing for the initial drop of this series, the weight distribution was calculated for the trailer, considering the tongue and wheels as separate units. See Table 1. The weight of the bed and simulated load was the main consideration in the actual design of the cushioning system, as these areas constitute the main weight factor of the trailer. This weight distribution coupled

TABLE 1
Assumed Weight Distribution for the M101

WEIGHT DISTRIBUTION (Empty)

Weight of Wheels	500 lbs.
Weight of Axle	100 lbs.
Bed and Frame-Forward of Axle	385 lbs.
Weight of Tongue Assembly	55 lbs.
Bed and Frame-To Rear of Axle	300 lbs.
Total Empty Weight	1340 lbs.

WEIGHT DISTRIBUTION (Loaded)

Weight of Wheels	500 lbs.
Weight of Axle	100 lbs.
Bed, Frame, and Load-Forward of Axle	1230 lbs.
Weight of Tongue Assembly	55 lbs.
Bed, Frame, and Load-To Rear of Axle	955 lbs.
Total Loaded Weight	2840 lbs.

with the results of the previous drop series[2] was used in the design of the cushioning system for the initial drop. Typical design calculations may be found in the appendix of the final report on the M37 Truck.[3]

Problems Encountered

Principal problems encountered were:

1. Weak frame bolts holding the bed to the frame.
2. Insufficient flat area under the bed of the trailer to allow the trailer and load to be cushioned without loadspreaders.
3. Weak flooring in the bed of the trailer allowing considerable bending to occur at impact.

The last two of these problems were solved by the use of three loadspreaders. Two of these were placed under the trailer so that they transferred the force of the cushioning stack directly to the floor of the trailer. The third loadspreader was placed in the bed of the trailer to more evenly distribute the force of the simulated load. (Note: Dimensional sketches of these loadspreaders are provided in a subsequent section of this report) Because of their complexity, the fabrication of these loadspreaders may not be practical from the field users standpoint. Consequently, further study is needed to reduce the complexity of the loadspreader system and to provide an effective system that is both simple and economical for use at high impact velocities. However, since the primary objective of this study was to determine the feasibility

of dropping at high impact velocities rather than the development of an ultimate system suitable for field use, no attempt was made to refine the design of the loadspreaders. With the prototype system described in this report for guidance, the development of a system for field use should not present any significant difficulties.

Lifting Rig

The M101 trailer used for this test series was rigged for drop by attaching lifting plates and shackles to each of the wheels. To facilitate the lifting and leveling of the vehicle, chains were attached to one end of each of three slings. One of the chains was passed through each shackle and hooked back on itself. The third sling was attached to the towing pintle in the same manner. This allowed for quick adjustment of each sling independently to achieve a level altitude of the vehicle for the drop.

The two sling ropes attached to the wheels were separated by a spacer beam to prevent damage to the vehicle and all three were attached to a large lifting shackle. This shackle was engaged by a helicopter hook which was released for the drop by the Fastax-Camera timing control. The entire rigging is shown in Fig. 1.

Platform

An 8 × 12-ft. plywood platform was designed and built,

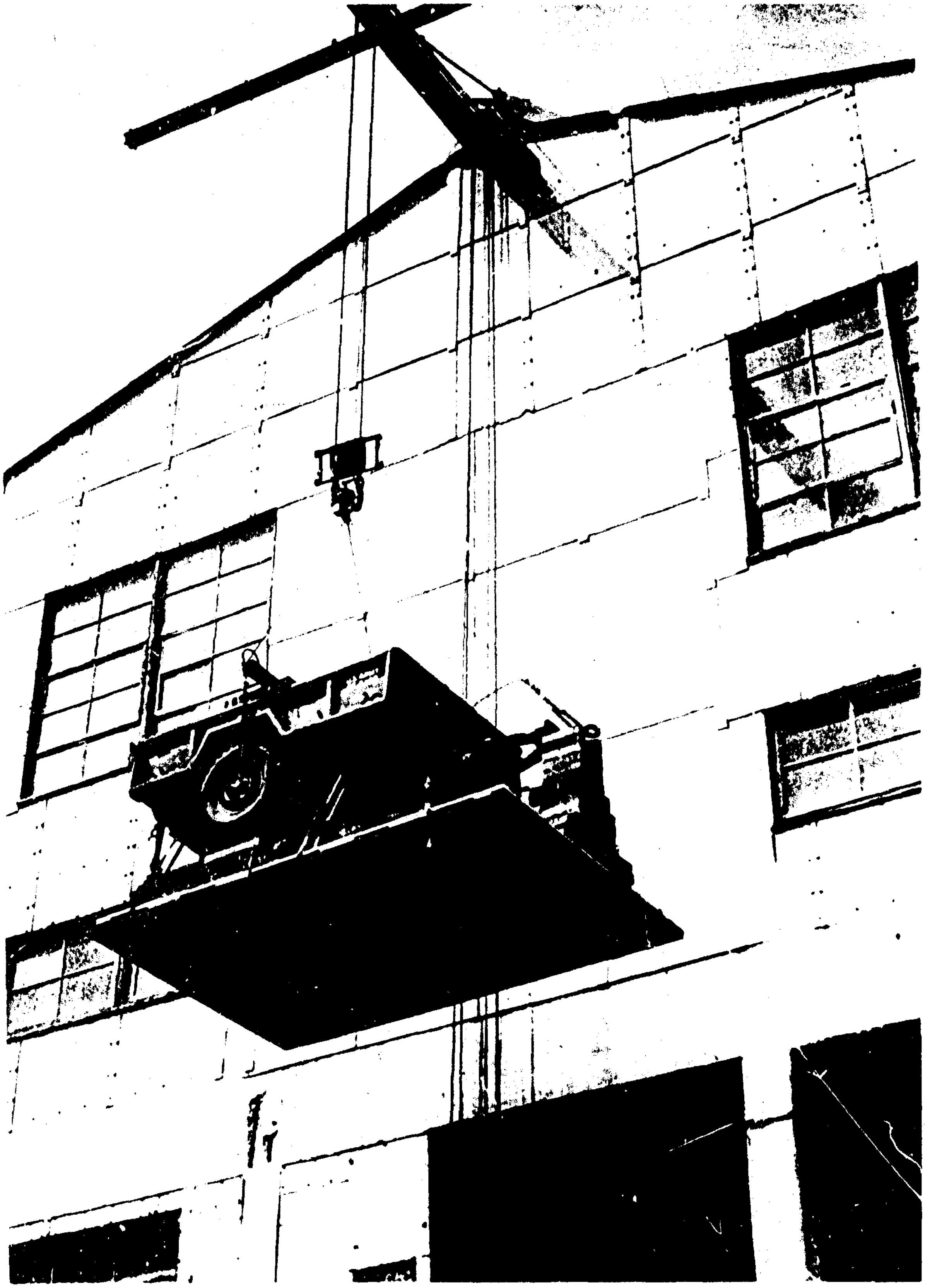


Fig. 1 Rigging for Lifting the M101

essentially to the specifications for the combat expendable platform described in TM 10-500-13. This platform performed very well and has been damaged only slightly by the five drops of this series.

Honeycomb

The cushioning material used throughout this series was 80-0-1/2 paper honeycomb purchased directly from the manufacturer. The average crushing stress determined for this honeycomb in a test series involving stacks in excess of 12 in. in height was determined to be 6430 lb/ft^2. This value was used in the calculation for all drops of this test series.

Instrumentation

Accelerometers were mounted on the vehicle in the following positions: Tongue, Center of Gravity, Rear Area. The front accelerometer was mounted to large 1-1/2-in. thick steel plates which had been bolted through the loadspreading pallet to the bed of the trailer. It was found in previous drop series that this procedure for mounting greatly reduced the vibration amplitude indicated by the accelerometer.

In addition to acceleration records which were recorded on both an oscillograph and magnetic tape, high-speed motion pictures were made of all drops. These pictures were studied for an indication of the efficiency of the cushioning system and for clues as to what changes should be made to improve the performance of

the system. Both prior to and at the completion of each drop, documentary photographs were taken. After a drop, the vehicle was carefully examined for any visible damage and then it was road-tested.

SUMMARY OF DROP PARAMETERS AND DAMAGE OBSERVED

M101-1; Height 10 ft.; Acceleration 20g.

For this initial drop, the weight distribution was calculated for the trailer considering the tongue and wheels as separate units. The weight of the bed and the simulated load was cushioned by two stacks placed under the loadspreaders at the quarter points of the loaded area. The wheels, axle, and tongue were considered separate masses and cushioned independently. The resulting cushioning reaction was balanced about the C.G. of the system to eliminate any angular movement during crushing.

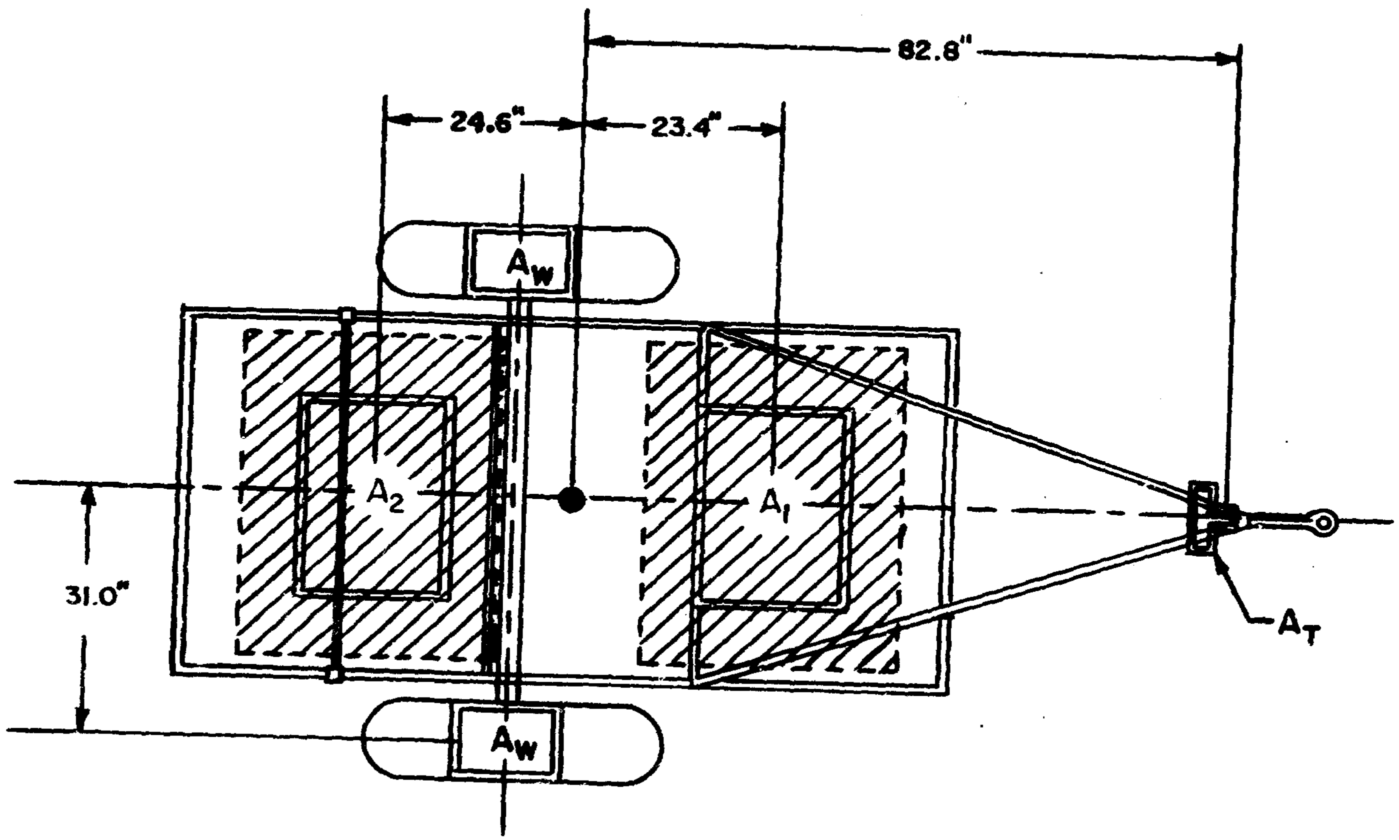
The position of the crushing stacks used for this drop, as shown in Fig. 2, remained the same throughout the test series. The areas shown in this figure provided for a design impact acceleration of 20g.

The system performed well with both front and rear cushioning stacks crushing to 65 percent.

There was no vehicle damage and no problems encountered. Accelerations were taken with accelerometers placed on the tongue, at the C.G., and at the rear of the load area. The results are presented in Table 4. Black and white 16mm film coverage was made from both the front and rear with full side 16mm Fastax coverage.

M101-2; Height 20 ft.; Acceleration 30g.

This drop was made from a height of 20 ft. and at a design



● C.G. Loaded

Crushing Stack

Loadspreader

Scale: 1/2" = 1'

Fig. 2 Stack Placement for M101 Drops

TABLE 2
Drop M101-1

Position	Stack Area	Dimension	Height
A_1	3.53 ft^2	2.2'×1.6'	9 inches
A_2	3.53 ft^2	2.2'×1.6'	9 inches
A_w	0.98 ft^2	0.85'×1.15'	9 inches
A_t	0.18 ft^2	0.43'×0.42'	9 inches

Total System Height = 63 inches

Including Honeycomb Crushing Stacks

impact acceleration of 30g in conformance with the test plan.

As mentioned previously, the same stack placement was used for this drop as the M101-1. However, the area of each stack was increased to provide the design acceleration of 30g. This cushioning configuration was used for the remainder of the drops.

The drop went as planned with the exception that during free fall, there was a small angular rotation of the system.

The cushioning system performed satisfactorily, crushing uniformly to 60 percent.

The only damage observed was the failure of one of the tie-down bolts which holds the bed to the frame. This failure was due to the nature of the tie-down design and the weakness of the type of bolt used for this function. The manner in which the head of the bolt is formed creates a severe stress concentration at the cross section immediately below the head. This causes the heads of the bolts to pop off.

M101-3; Height 30 ft.; Acceleration 30g.

This drop was designed to further study the effects of high-impact velocities on the damage susceptibility of the vehicle and to more closely determine a maximum design acceleration for this particular vehicle.

During the free-fall period of this drop, the system rotated so that the rear of the platform was 18 in. lower than the front at impact. Severe pitching of the load and uneven crushing of the system resulted.

The floor of the trailer was slightly bent and after rebound the left shock absorber impacted on the main buildup stack and was bent, thereby rendering the shock absorber inoperative (See Fig. 3).

The rear cushioning stack crushed to 80 percent while the front crushed to only 65 percent.

The trailer survived extremely well considering the rotational component at impact. No damage was incurred which would cause the vehicle to be inoperable.

After thorough study of this rotational problem, it was concluded that air-resistance acting on the bottom of the platform was causing the system to rotate because the C.G. of the system was located to the rear of the center of the air resistance reaction, i.e., the center of the platform. It was determined that the moment of inertia of the system was small enough to allow the unbalanced forces acting on the platform to induce the angular rotation observed. This problem was eliminated for M101-4 by moving the trailer forward on the platform so that the C.G. of the system was over the center of the platform. If in actual airdrops the drag forces of the parachute are centered over the C.G. of the vehicle, care should be taken that the C.G. of the vehicle is directly over the center point of the platform. This is necessary to balance the forces acting on the system.

Fig 3 Shock Absorber Damage after M101-3

M101-4; Height 40 ft.; Acceleration 30g.

This drop was made in accordance with the test plan. There was no angular movement detected and no major problems encountered.

The system crushed to 65 percent with all stacks crushing uniformly.

A bed tie down bolt was again broken; this problem, however, is due to the weakness of the type of bolt used for this purpose and could probably be prevented by using a bolt or fastener with a better design.

The cushioning system used for this drop is considered to be an effective design for use at high impact velocities and was further tested by M101-5. The present system provides for a design impact acceleration of 30g. This value is considered as an optimum value since it provides for sufficient area to prevent stability problems in the cushioning stacks without subjecting the vehicle to extremely high accelerations upon impact.

M101-5; Height 47.25 ft.; Acceleration 30g.

This drop was made to prove out the cushioning system used for previous drops and to see if any additional problems of vehicle or cushioning design occur at higher impact velocities.

The only modification of the cushioning system from the design of M101-4 was the additional stack height necessary to dissipate the additional energy of the higher drop. The complete system ready for drop is shown in Fig. 4.

The system performed well, crushing uniformly to 65 percent,

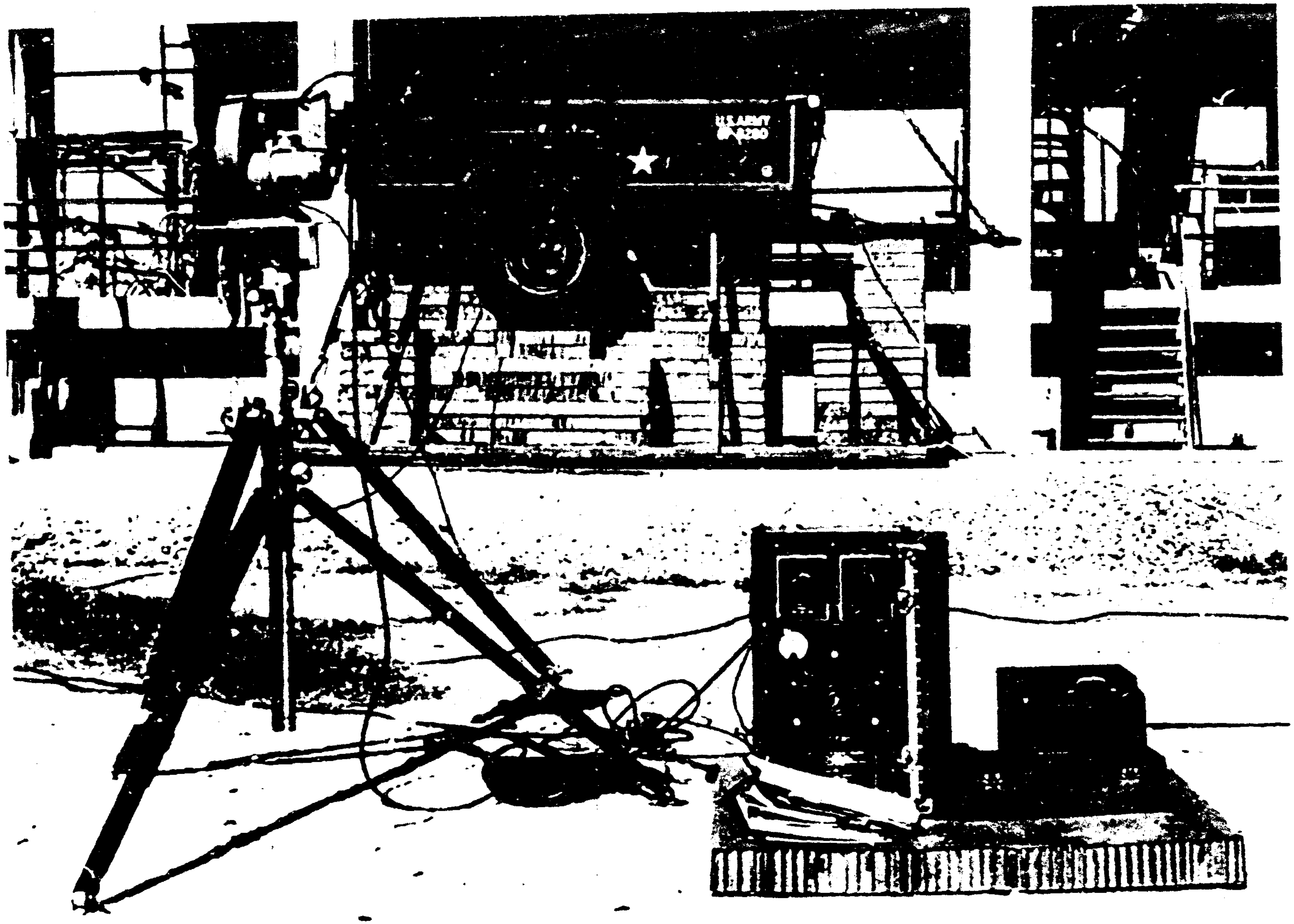


Fig. 4 The System before M101-5

with no damage to the vehicle being observed. Figure 5 shows the system after this final drop of the series.

Although the cushioning system used for this drop performed very well, it cannot be considered the ultimate design for the vehicle. As related previously, the effectiveness of the system depends heavily on the use of a system of loadspreaders. Although the design of these loadspreaders is not overly complex, it is not considered feasible to use this type of spreader in an actual air drop situation. However, since this test series was a feasibility study rather than the development of an ultimate system suitable for field use, no attempt was made to refine the design of the loadspreader system. With the prototype system shown in Fig. 6 as a guideline, the development of a system for field use should not present any significant difficulties.

The trailer was examined thoroughly after this drop to be certain that no damage was overlooked. It was determined that the only permanent damage was the slight bending of the floor of the bed encountered during M101-3.

The problem with the bed tie-down bolts is attributed, as indicated previously, to a faulty design which causes large stress concentrations to develop where the shank joins the head of the bolt.

It became evident during a previous test series involving the dropping of vehicles with simulated loads, that considerable deformation of the bed occurred unless the loading forces could be carried into the frame through some means other than the

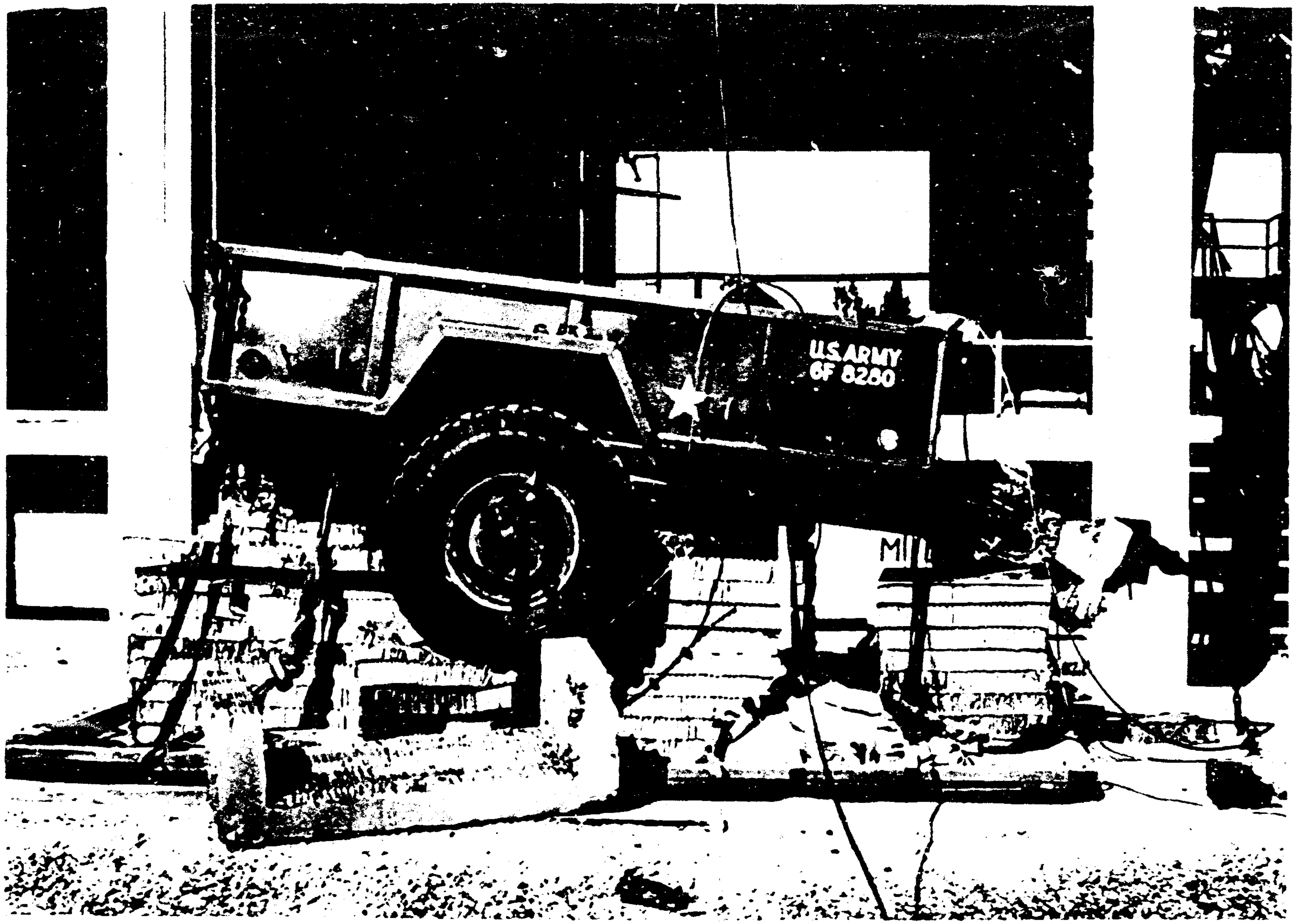
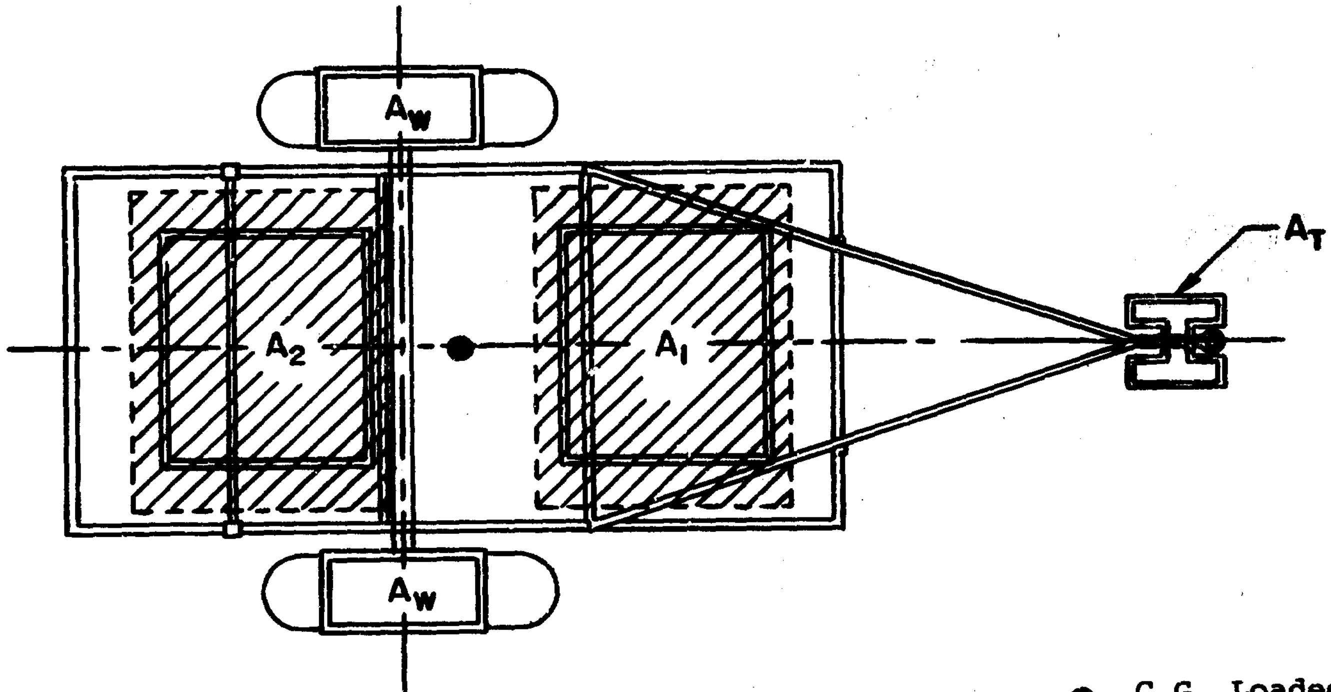


Fig. 5 The System after M101-5



C.G. Loaded

Crushing Stack

Loadspreader

Scale: 1/2" = 1'

Fig. 6 The Loadspreader System for M101 Drops

TABLE 3
Drop M101-5

Position	Stack Area	Dimension	Height
A_1	5.26 ft^2	2.2'×2.6'	24 inches
A_2	5.26 ft^2	2.2'×2.6'	24 inches
A_w	1.45 ft^2	0.85'×1.7'	24 inches
A_t	0.30 ft^2	0.55'×0.55'	24 inches

Total Area 14.90 ft^2

Total System Height = 75 " Including Honeycomb Cushioning Stacks

relatively light metal floor in the bed. The loadspreader designed and built for this purpose was effective in reducing the bending of the bed. It is suggested that a similar loadspreader be provided during actual drops if a load is to be dropped in the vehicle (See Fig. 7). It probably would be better to drop the vehicle empty and to place the load that normally would be dropped in the trailer on the platform, protecting it, of course, by the use of honeycomb.

Average accelerations and peak accelerations for all the drops are shown in Table 4. In general, the measured average acceleration is less than the design acceleration. This phenomenon has been observed in previous studies and is attributed to the flexibility of the vehicle structure which actually provides some shock mitigation for itself. In Table 4, Column 8, the integral of the acceleration record is shown. The discrepancies between the impact velocity and the acceleration integration are due mostly to the difficulty inherent in determining just where to stop the integration.

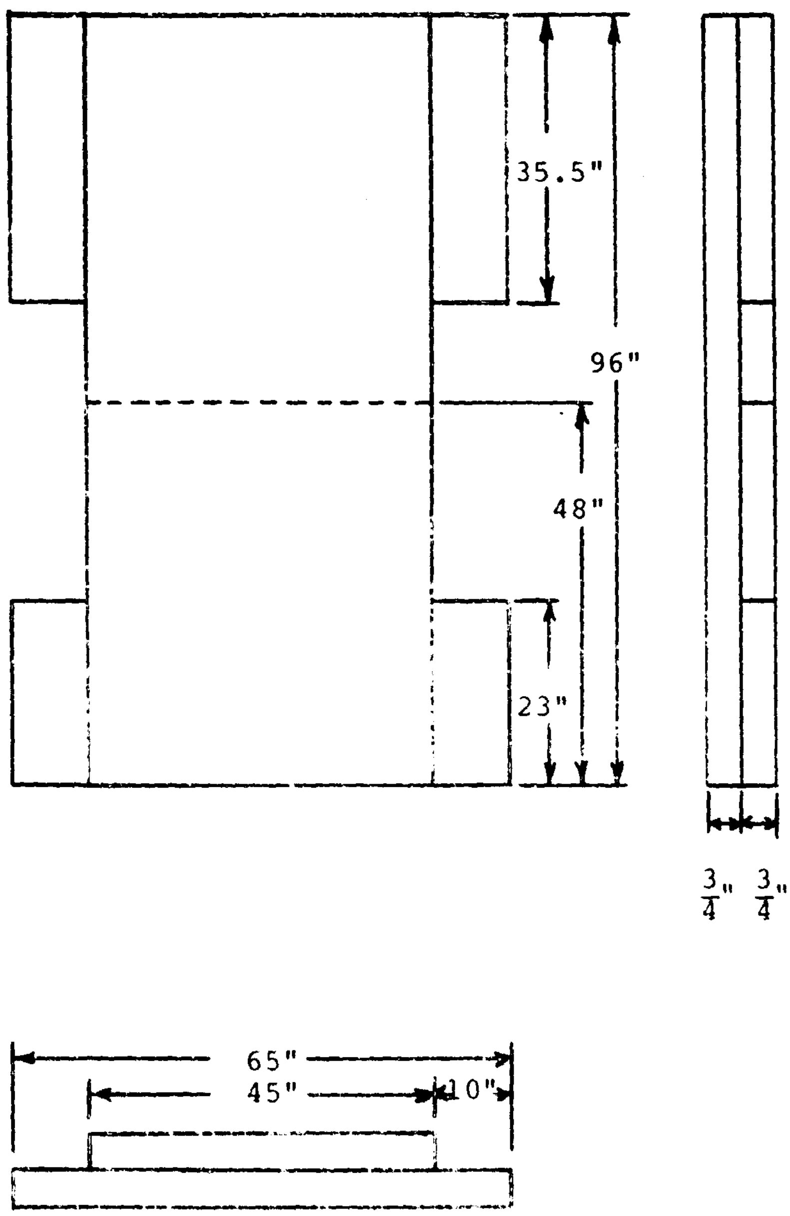


Fig. 7 Plywood Load Pallet for 3/4-Ton Trailer M101

Drop Number	Area	Height	Design Accel.	Peak Accel.	Ave. Accel.	Impact Vel.	Vel. Change
						$\sqrt{2gh}$	$\int a\,dt$
M101-1	Front	10'	20 g's	34.0 g's	16.5 g's	25.4 fps	26.5 fps
	C.G.	"	"	39.0	16.3	"	26.6
	Rear	"	"	43.0	15.3	"	28.0
M101-2	Front	20'	30 g's	49.1	25.8	35.9 fps	37.4 fps
	C.G.	"	"	44.5	26.5	"	36.7
	Rear	"	"	51.2	26.1	"	36.0
M101-3	Front	30'	30 g's	48.7	27.4	43.9 fps	46.1 fps
	C.G.	"	"	45.6	28.3	"	44.5
	Rear	"	"	48.9	27.2	"	45.5
M101-4	Front	40'	30 g's	No Record	No Record	50.0 fps	No Record
	C.G.	"	"	32.1	26.1	"	51.6
	Rear	"	"	34.0	25.6	"	52.3
M101-5	Front	47.25'	30 g's	No Record	No Record	55.2 fps	No Record
	C.G.	"	"	58.8 g's	24.7	"	58.8
	Rear	"	"	44.4 g's	36.1 g's	"	58.0

TABLE 4
Acceleration Data for M101 Trailer Drops

CONCLUSIONS

1. The M101 3/4-ton trailer can be dropped from a height of 50 ft. to land with an impact velocity of 57 fps using essentially the same techniques used for dropping at 25 fps.

2. A cushioning system designed for 30g average acceleration provides adequate protection for the vehicle. This design acceleration could be used even at low-velocity drops to reduce the required stack heights to a minimum.

3. Provisions should be made for palletizing the load in the trailer bed, if the load consists of concentrated masses.

4. Problem areas encountered could be at least partially resolved by redesigning certain parts of the vehicle as follows.

   a. Change the bed tie-down bracket to eliminate the moment arm between the bolt and the point of contact of the clamp.

   b. Change the specifications for the tie-down bolts to provide for a stronger fastener.

   c. Provide additional cross-bracing between the structural members now used.

   d. Specify a heavier gage flooring and design the frame cross-bracing to provide a uniform cushioning area.

5. It probably would be more convenient and more economical to drop the trailer empty, and cushion the load separately on the platform. Insufficient information is available at present, however, for reaching a definite conclusion on this point.

6. It is evident from the results of this series of tests that military vehicles can be safely dropped at impact velocities in excess of 50 fps. At the present time, it would be desirable, however, to drop a prototype vehicle of each type, under controlled conditions to determine possible sources of weakness, and to develop the details of the cushioning system for the particular vehicle under consideration.

REFERENCES

1. Turnbow, J. W. and C. C. Steyer, *Cushioning for Air Drop, Part II, Air Drop Cost Analysis*, Structural Mechanics Research Laboratory, The University of Texas, Austin, 1955.

2. Shield, Richard and Clarke Covington, *Fragility Studies, Part IV, Cargo Trailer, M1Cl, 3/4-Ton*, Structural Mechanics Research Laboratory, The University of Texas, Austin, 1960.

3. Wiederanders, D. G., W. L. Guyton and E. A. Ripperger, *Ground Impact Shock Mitigation, Cargo Truck, 3/4-Ton M37*, Engineering Mechanics Research Laboratory, The University of Texas, Austin, 1966.

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) The University of Texas Austin, Texas	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

GROUND IMPACT SHOCK MITIGATION CARGO TRAILER M101, 3/4-TON

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Third in series of three dealing with high velocity drop.

5. AUTHOR(S) (Last name, first name, initial)

Wiederanders, David G.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1967	29	3

8a. CONTRACT OR GRANT NO. DA19-129-AMC-582(N) b. PROJECT NO. 1F121401D195 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 68-51-AD 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) EMRL TR 1025

10. AVAILABILITY/LIMITATION NOTICES

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	SPONSORING MILITARY ACTIVITY
	U. S. Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

The present investigation and test series involving the M101 3/4-ton cargo trailer has consisted of five drops of the vehicle at impact velocities ranging from 25.4 fps, for the initial drop, to 55 fps for the fifth and final drop of the series. During the series, the design impact acceleration was varied from 20-30g. The cushioning system used for each drop of the series is described and the damage sustained by the vehicle during that drop is discussed. It is concluded that this vehicle can be dropped at impact velocities up to 50 fps without any damage, if a properly designed cushioning system is employed to dissipate the energy of the drop.

Recommendations for improvements, from the airdrop standpoint, in the design of the vehicle, are included.

DD FORM 1 JAN 64 1473

Unclassified

Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Cushioning	8		6			
Cargo vehicles	9		7			
Trailers	9		7			
Armed Forces supplies	9		7			
Honeycomb construction	10					
Air-drop operations	4		4			
Impact shock	8		6			

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through ________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through ________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

Unclassified
Security Classification